Ex post impact assessment of NRM research in the arid and semiarid areas: The case of The Mashreq/Maghreb Project experience

The impact of Cactus in alley cropping in the Tunisian case study

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Activity 1

Technology and site characterization

Technology characterization

Plate 1.3. In rural areas cactus is planted close to houses and used as a fodder bank for livestock (Central Tunisia, 200 mm average rainfall)

Brief history…

- XV century… Introduction in Andalusia on the return of Columbus' first expedition from America
- XVII to XIX: implementation in North Africa with the return of Moors to their homeland in NA
- 1930… Extension of cacti with international project (FAO, WFP)
- 1975… Establishment of national incentives and subsidies by the tunisian goverment
- 1990… National strategies for rangeland imporvement / MM project: research on technology packages to rehabilitate degraded range land
- 1998: development of cactus in alley cropping in the Zoghmar community in parternship with development agencies (OEP, CRDA…)

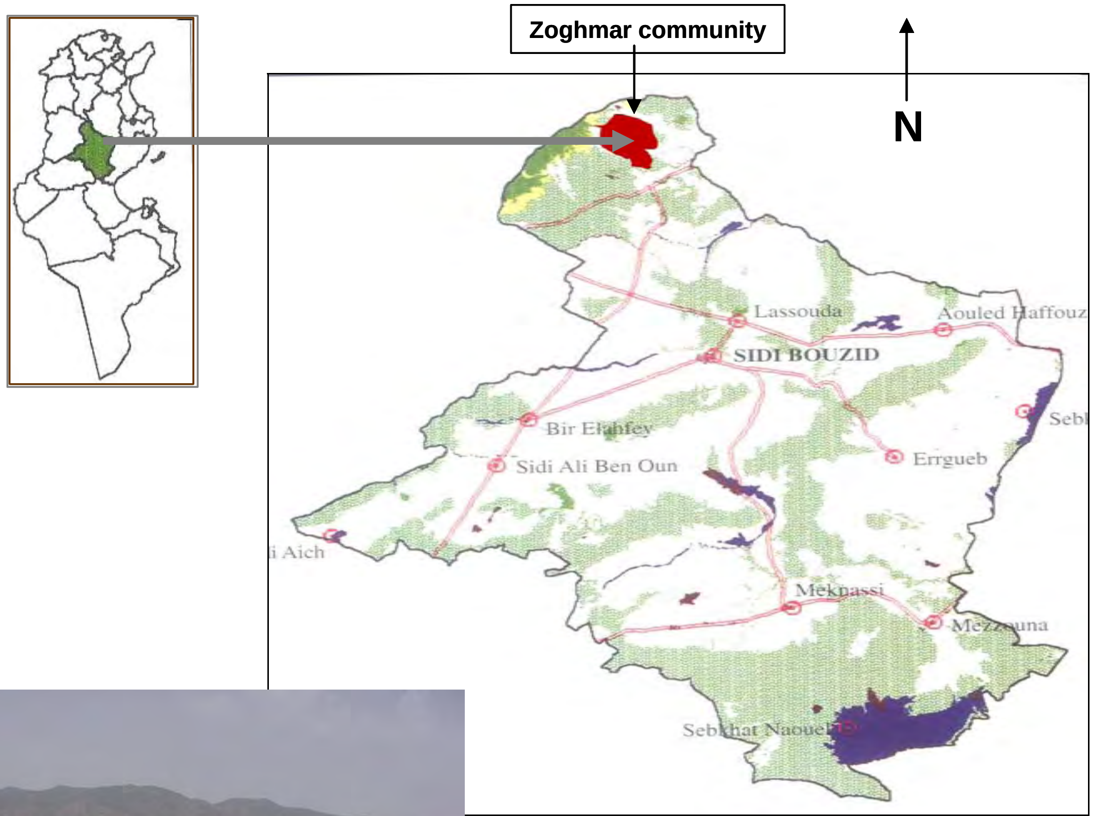
Multi functional Role of Cacti in Alley cropping

- **Expected Environmental impacts**
  - Controlling erosion and runoff
  - **Enrichment in organic matter and nitrogen**
  - **Top soil structural stability → roots**
  - Prevention and control of top soil loss due to wind
  - Conservation of biodiversity: food and shelter for many widlife secies
  - Combat desertification
  - Water saving

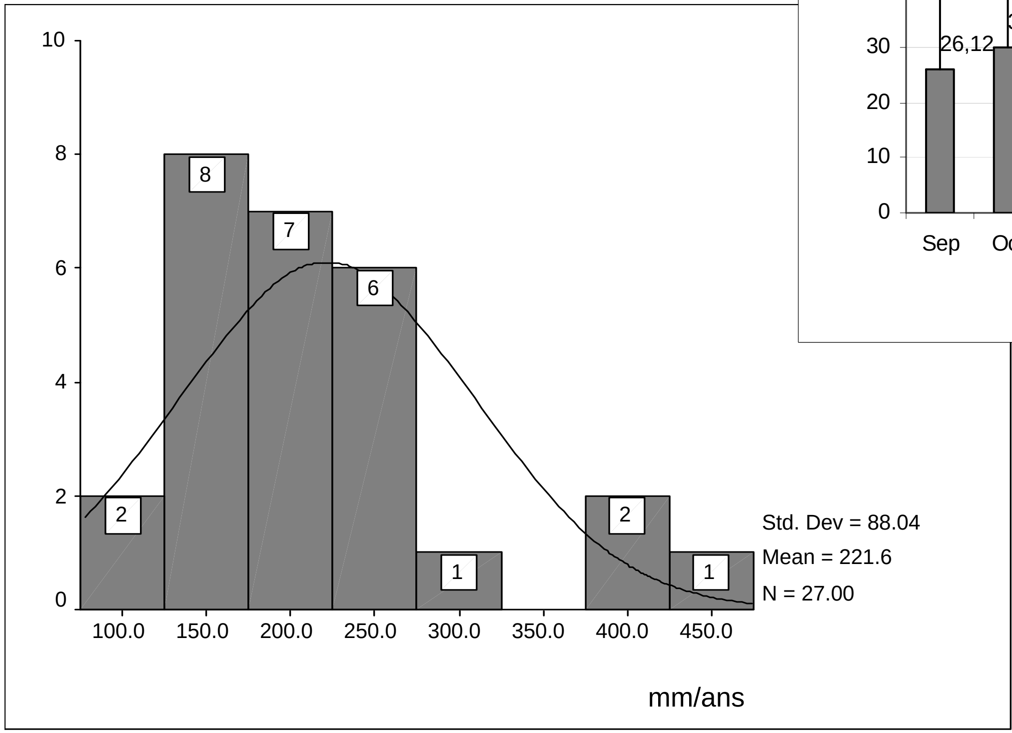
- **Expected socio-economic impacts:**
  - Testimony of land rights without no land registry
  - Multi uses: forage, food, potential market, medicinal applications,
  - **Low cost feed** in drought years

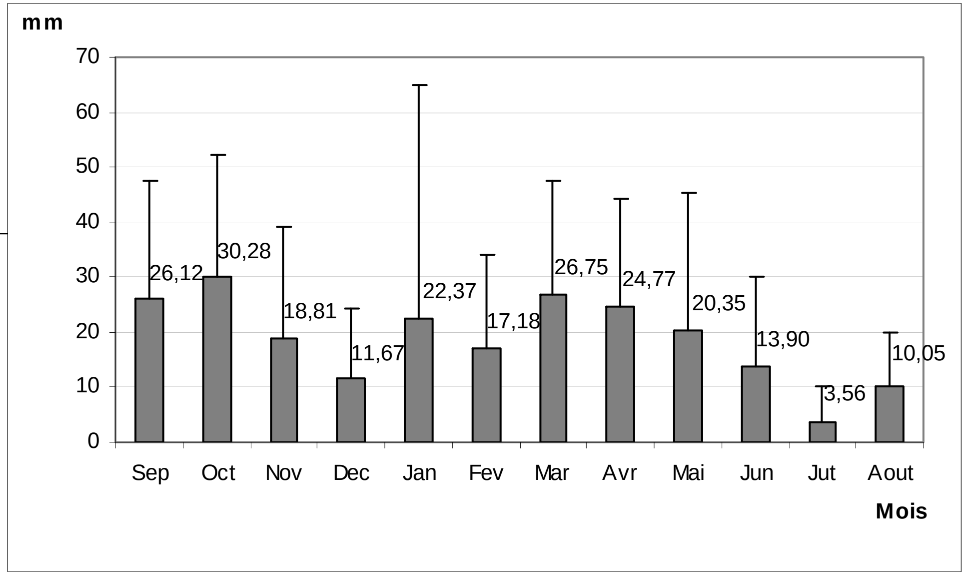
- **Expected agronomic impacts**
  - **Cereal grain yield increase**
  - **Biomass increase**

Site characterization

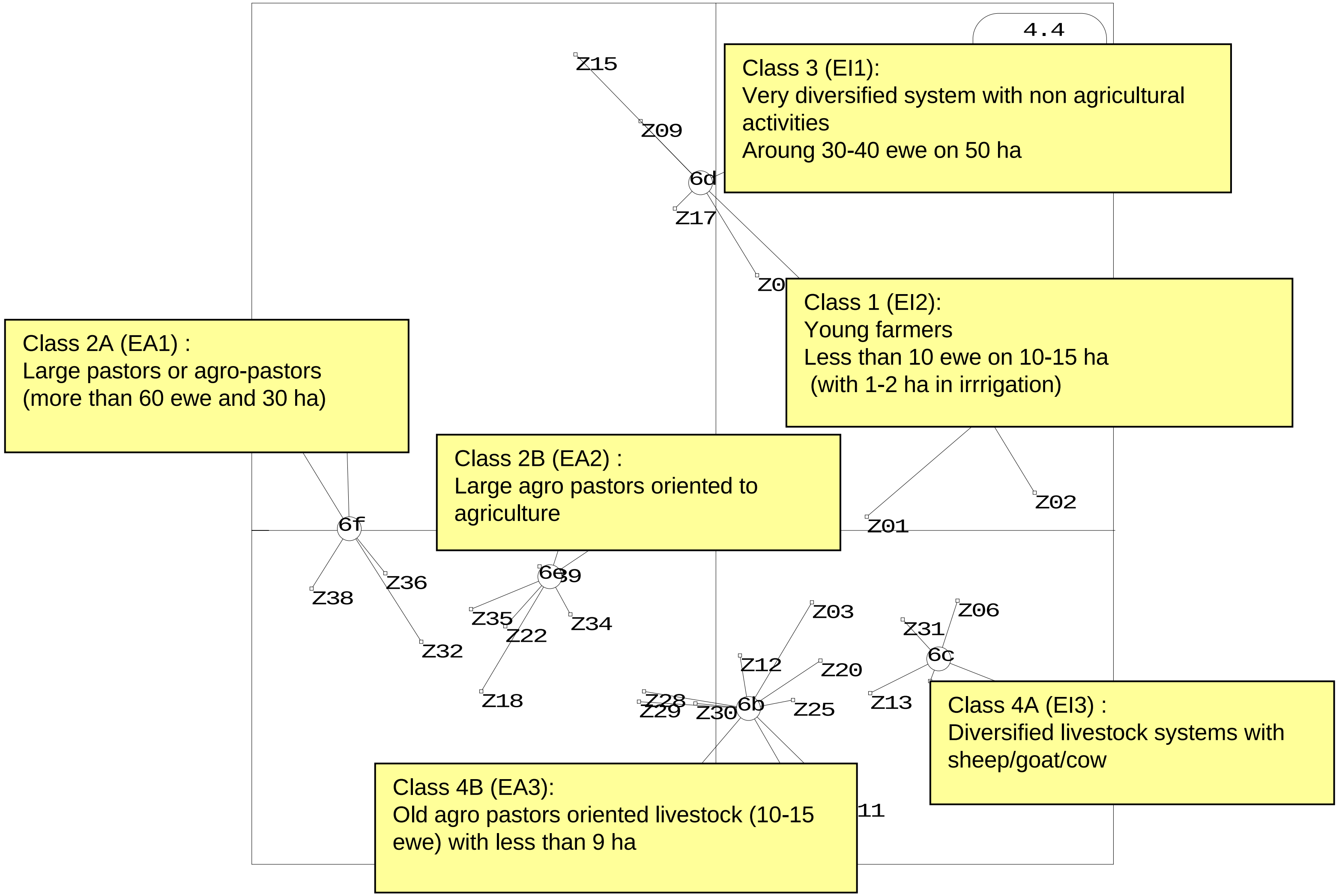


Annual and monthly rainfall frequency calculated for 27-years period





Farming systems characterization

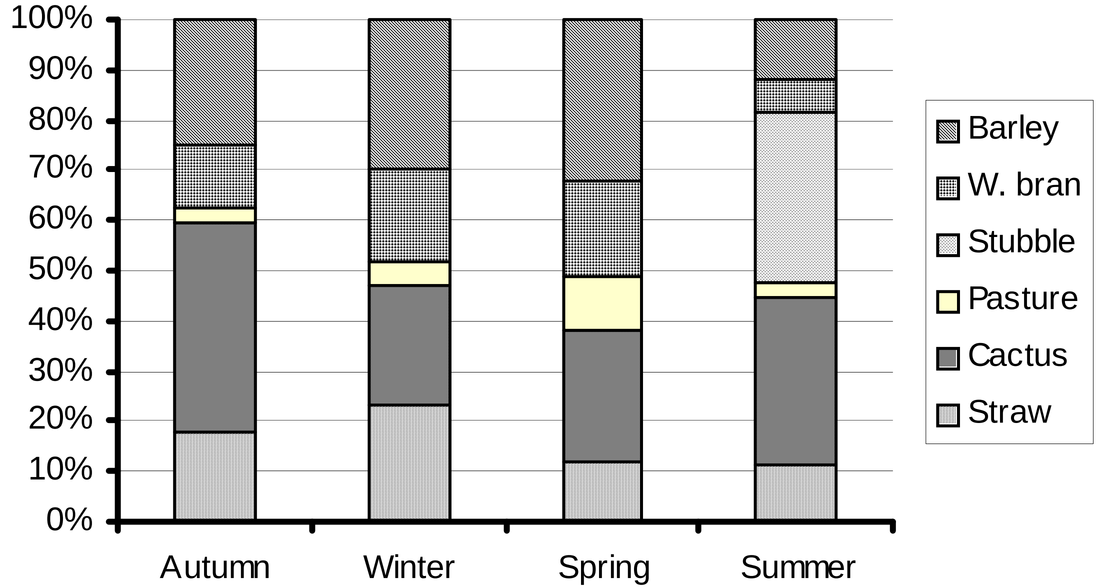


Feed price variability with climatic conditions

Feed	Good year	Medium year	Poor year	Dry year
Barley grain	0.170	0.170	0.170	0.136
Straw	0.084	0.178	0.285	0.427
Hay	0.151	0.230	0300	0.506
Bran	0.160	0.160	0.160	0.160
Cactus	0.022	0.02	0.022	0.028
Feed Block	0.170	0.170	0.170	0.170

Diet composition (dry matter basis) for sheep raised in the Community of Zoghmar, Sidi Bouzid (Ben Salem, 2000)

Plate 1.4. Cactus pads are commonly chopped in slices by hand; this procedure is time-consuming



Activity 2

Identification and Quantification of
Performance Indicators

Agronomic and environmental impacts

	NR	Cactus in AC on NR	Barley	Cactus in AC with barley
Yield	3.3 Tons/ha	4 Tons/ha	0.8 Tons./ha	2.2 Tons/ha
Biomass				
Carbon soil				
Nitrogen Soil				
Organic matter				
Roots				

Results at the end of june

Impact of technology adoption on livestock activity

A stochastic frontier translog cost function was estimated using maximum likelihood technique:

$$\begin{aligned}\ln C_{kt} &= \alpha_0 + \sum_i \alpha_i \ln w_{kit} + \tfrac{1}{2}\sum_i \sum_j \alpha_{ij} \ln w_{kit} \ln w_{kjt} + \alpha_L \ln L_{kt} + \sum_i \alpha_{Li} \ln L_{kt} \ln w_{kit} \\ &+ \alpha_y \ln y_{kt} + \alpha_t t + \tfrac{1}{2}\alpha_{tt} t^2 + \sum_i \alpha_{ti} t \ln w_{kit} + \alpha_{tL} t \ln L_{kt} + \alpha_A A_{kt} + \alpha_{CAC} CAC_{kt} \\ &+ \sum_i \alpha_{CAC,i} CAC_{kt} \ln w_{kit} + \alpha_{CAC,L} CAC_{kt} L_{kt} + \alpha_{CAC,t} CAC_{kt} t + \varepsilon_{kt}\end{aligned}$$

As expected, there is a **negative relationship between total cost and cactus acreage**. Indeed, a one ha increase in cactus plantation reduces total cost of livestock activity by 0.133 % while 1ha increase in pasture or cereal land reduce total cost of livestock activity by 0.11%.

Total Factor Productivity decomposition (Mundlak, 95,98)

	Scale	A	Labor	Cactus	TC	CE	TFP
1999-2002*	**1.0**	**-4.0**	**-0.4**	**1.5**	**-16.4**	**0.5**	**-18.1**
2002-2003	**2.7**	**10.4**	**0.2**	**1.1**	**11.8**	**-21.3**	**4.9**

*Figures represent average annual rate

A: total area; TC: technology change; CE: cost efficiency

Cactus adoption has enhanced productivity growth by 1.5 percent during drought period.

This contribution is somewhat low but it is worth to precise that till 2003, cactus in Alley cropping plantation was still young and thus unexploited.

Efficiency analysis

Figure 1. Kernel Density function: Inefficiency level in 1999

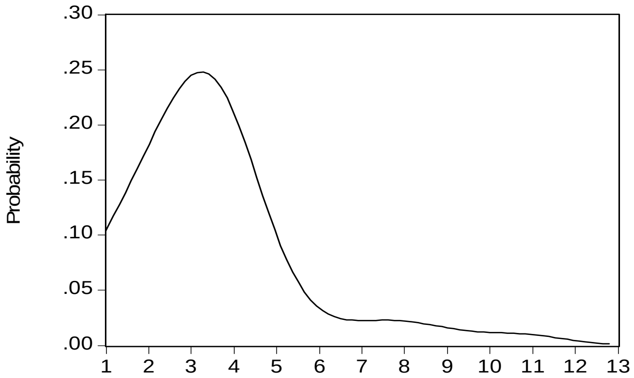


Figure 2. Kernel Density function: Inefficiency level in 2002

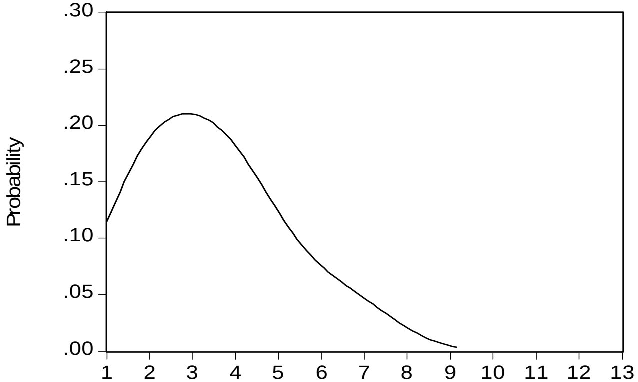
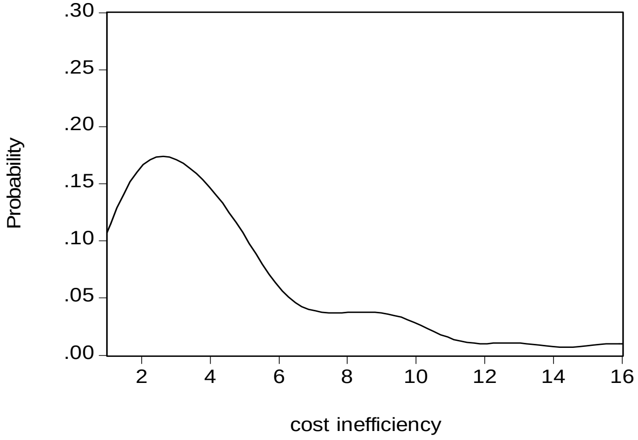


Figure 3. Kernel Density function: Inefficiency level in 2003



- The inefficiency distribution in 2003 dominates both 2002 and 1999
- Indeed, an increase in cactus acreage reduces degree of cost inefficiency

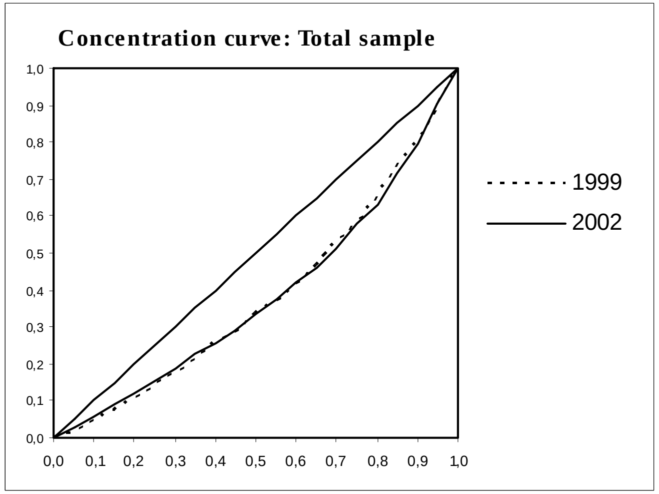
Table 2.6 : Determinants of inefficiency

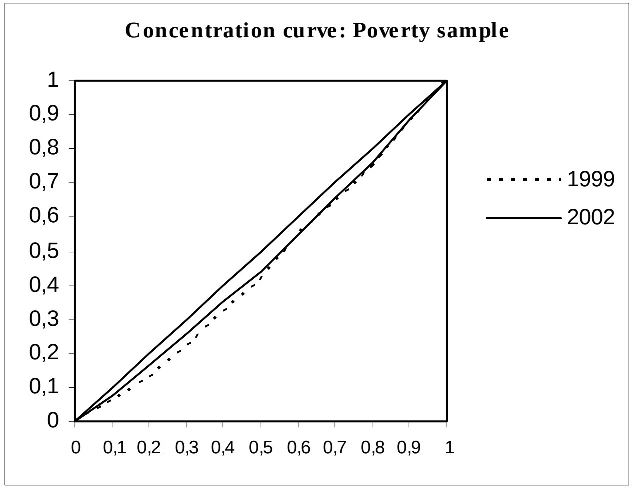
	coefficient	t-ratio	p. value
Interc.	-2.587	-2.457	0.0157
REV	0.005	0.287	0.7750
age	-0.001	-0.267	0.7896
F	0.016	0.476	0.6353
INST	0.007	0.085	0.9327
IR	-0.011	-0.085	0.9328
FEM	-0.062	-1.091	0.2777
Qf	0.403	6.585	0.0000
Qw	-0.041	-0.716	0.4755
L	0.286	0.877	0.3826
CAC	**-0.051**	**-3.270**	**0.0015**

Social indicators

Poverty indicators and expenditure distribution

	Poverty line	Head count (poor/n) (in %)	Poverty Gap $((y-p_m)/y$	Sen Indicator	Gini total	Gini pov
1999	221	20.00	**11.01**	4.28	0.245	0.117
2002	230	20.51	**4.94**	1.86	0.241	0.043





Activity 3

Valuation of the benefit and Cost of the Technology

Hypothesis

- Benefit cost analysis conducted for 1 ha
- Two alternative: cladode market (0.03 DT/kg); no cladode market (equivalent energy)
- Two scenarios: With subsidies and without subsidies
- Two beneficiaries:
  - Farmers: subsidies are products
  - Project: subsidies are costs

Cactus on marginal cereal land

Item	Hypothesis*	Net discounted value (DT)	Internal rate of return (IRR)	Recovery time (year)
(S1) Project with OEP incentives	(1)	518.58	26%	6
	(2)	299.77	20%	7
(S2) Project without OEP incentive	(1)	642.92	34%	5
	(2)	424.11	28%	5
(S3) Farmers with OEP incentive	(1)	866.85	111%	3
	(2)	648.04	100%	3
(S4) Farmers without OEP incentive	(1)	429.62	34%	5
	(2)	310.27	29%	5
(S5) Farmers with OEP incentive But real cost	(1)	1012.30	***	1
	(2)	793.5	***	1
(S6) Farmers without OEP incentive But real cost	(1)	575.08	95%	3
	(2)	455.73	88%	3

Cactus on degraded pasture land

Item	Hypothesis*	Net discounted value (DT)	Internal rate of return (IRR)	Recovery time (year)
(S1) Project with OEP incentives	(1)	111.22	13%	9
	(2)	-186.47	5%	11
(S2) Project without OEP incentive	(1)	235.57	16%	8
	(2)	16.76	11%	9
(S3) Farmers with OEP incentive	(1)	459.5	30%	6
	(2)	240.69	22%	7
(S4) Farmers without OEP incentive	(1)	22.27	11%	9
	(2)	-97.08	6%	11
(S5) Farmers with OEP incentive But real cost	(1)	604.95	68%	5
	(2)	386.14	52%	5
(S6) Farmers without OEP Incentive But real cost	(1)	167.72	19%	7
	(2)	43.38	13%	8

Benefit Cost analysis

Types of land	Scenarios	Net discounted value (in thousand DT)	Internal rate of return (IRR)	Recovery time (year)
Marginal cereal land	With pad market	1,371	46%	7
	Without pad market	217	18%	10
Pasture land	With pad market	1,320	45%	7
	Without pad market	221	17%	14

Hypothesis:
- No taking into account the research cost
- The cost is 500 DT/ha with the OEP intervention
- The cost is 102 DT/ha without OEP intervention (Labour 4DT/day)

Activity 4

Technology Adoption Indicators

Adoption indicators

	A	B	C	D	E
Date	2000	2001/02	**2002**	2002/03*	2004
Total number of farms (sample)	40	39	**317**	40	40
Adopters	15	14	**97**	26	18
Adoption rate (%)	**37.5**	**35.9**	**30.6**	**65.0**	**45.0**
Total cactus area	204	153	**726**	101	
cactus area in alley cropping	122		**419**		
Potential area for cactus in alley cropping in the area of the project			**??**		
Potential area for cactus in alley cropping in Zoghmar	536	711	**1475**	533	
Degree adoption for cactus	**38.1**	**21.5**	**40.7**	**18.9**	
Degree adoption for cactus in alley cropping in the project**			**??**		
Degree adoption for cactus in alley cropping in Zoghmar***	**26.9**		**28.4%**		

Adoption indicators per farm types

Small Ruminants	Nb farm	% farm	Adoption rate (%)	Cactus AC (in Ha)	% cactus (ha)	Adoption degree (%)
> 50	26	0.08	46%	87	0.21	17%
25-50	55	0.17	38%	127	0.30	16%
15-25	61	0.19	36%	91	0.22	18%
< 15	120	0.38	26%	86	0.20	13%
0	55	0.17	2%	28	0.07	13%
Total	317			419		

Farm size	Nb Farm	% farm	Adoption rate (%)	Cactus AC (in Ha)	% cactus AC	degree of adoption	Average cactus area (in ha)
> 15 ha	67	3%	31%	240	57%	21%	3.58
10-15 ha	66	27%	24%	83	20%	13%	1.25
5-10 ha	85	26%	30%	73	17%	16%	0.85
1-5 ha	87	20%	15%	23	5%	11%	0.26
0 ha	12	21%	0%	0	0%	0%	0
Total	317			419			

Determinants of technology adoption

Censored regression (dependent variable: acreage of cactus in alley cropping)

Method: ML - Censored Normal (TOBIT) (Quadratic hill climbing)
Included observations: 33
Left censoring (value) at zero

	Coefficient	Std. Error	z-Statistic	Prob.
Intercept	0.3437	16.475	0.0208	0.9834
Area	0.7811	0.2307	3.3858	0.0007
Labour	-5.2940	3.1171	-1.6983	0.0894
Livestock size	-0.0484	0.0517	-0.9361	0.3492
Off farm	0.7282	0.6631	1.0980	0.2722
Household size	-4.5758	1.3472	-3.3963	0.0007
AGE	0.7813	0.2516	3.1050	0.0019
INSTruction	-9.7073	5.4707	-1.7744	0.0760
IRrigation	19.829	6.3850	3.1055	0.0019

Effect of subsidies on technology adoption- Method of contingency

Figure.4.1
Kernel Density of acereage allowed to CAC

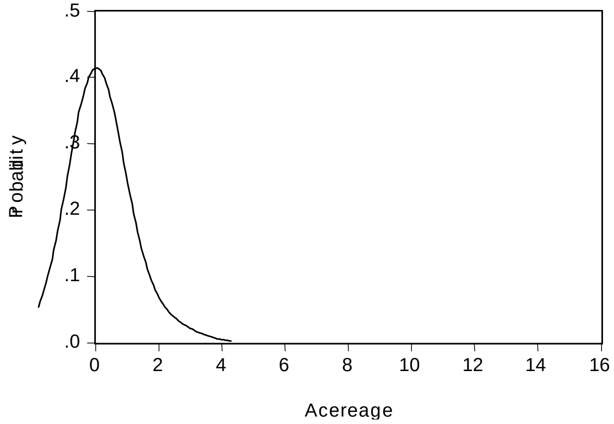


Figure 4.2
Kernel Density of acereage allowe

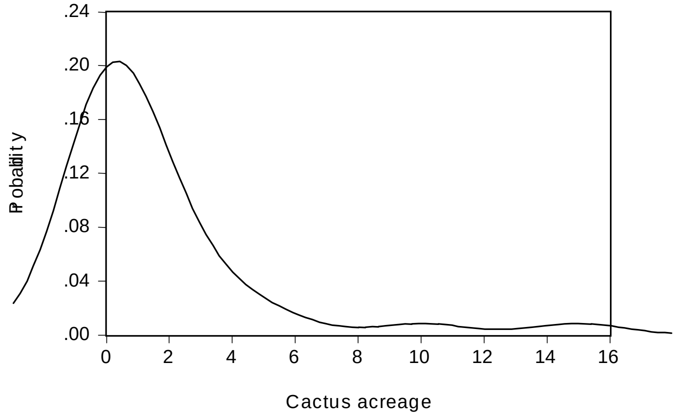


Figure.6
Kernel Density of acereage allowed to CAC with S2

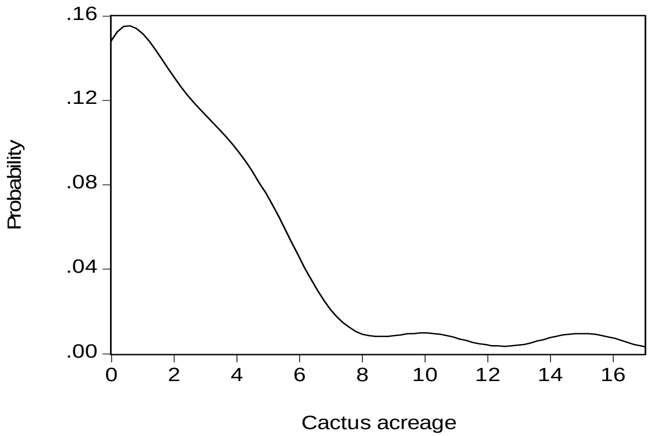
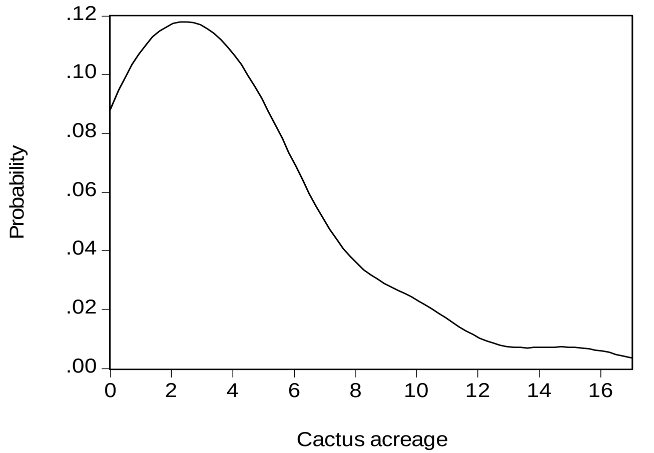


Figure.7 Kernel Density of acereage allowed to CAC with S3



Activity 6

Modelling Approach For Ex Post Impact Assessment

NRM research project- Cactus in Alley Cropping

Environment

-Soil conservation (Soit texture, soil enrichment, control soil loss)

-Controlling erosion

-Water management (avoid runoff,permeability and water storage)

-Main biodiversity

Reproduction
Ecology
Efficiency

Economy

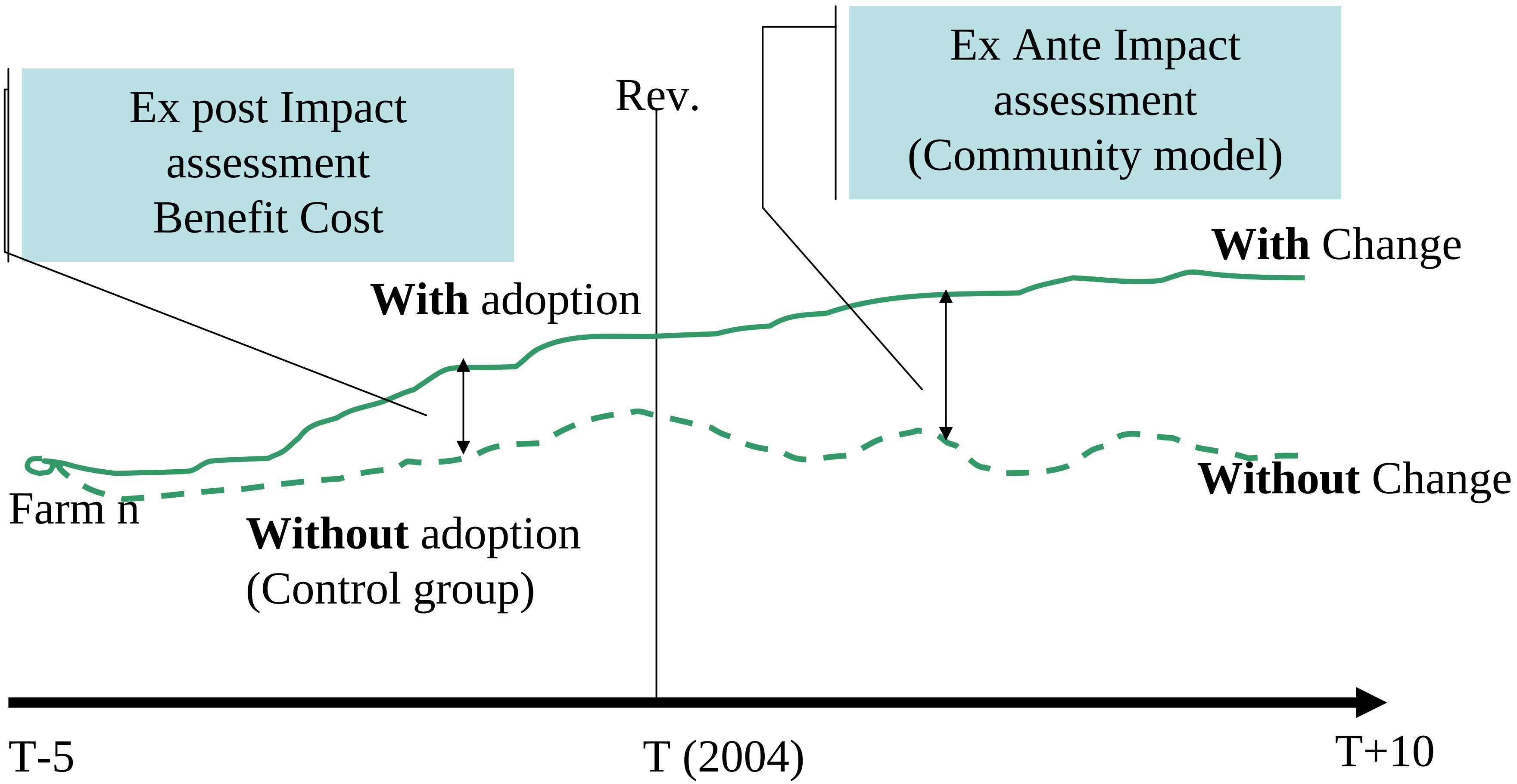
-Feed stock, low cost feed

-Diversification (fruit, cladode market)

-biomass increase

-Testimony land rights

Classical view: Ex ante & ex post assessment

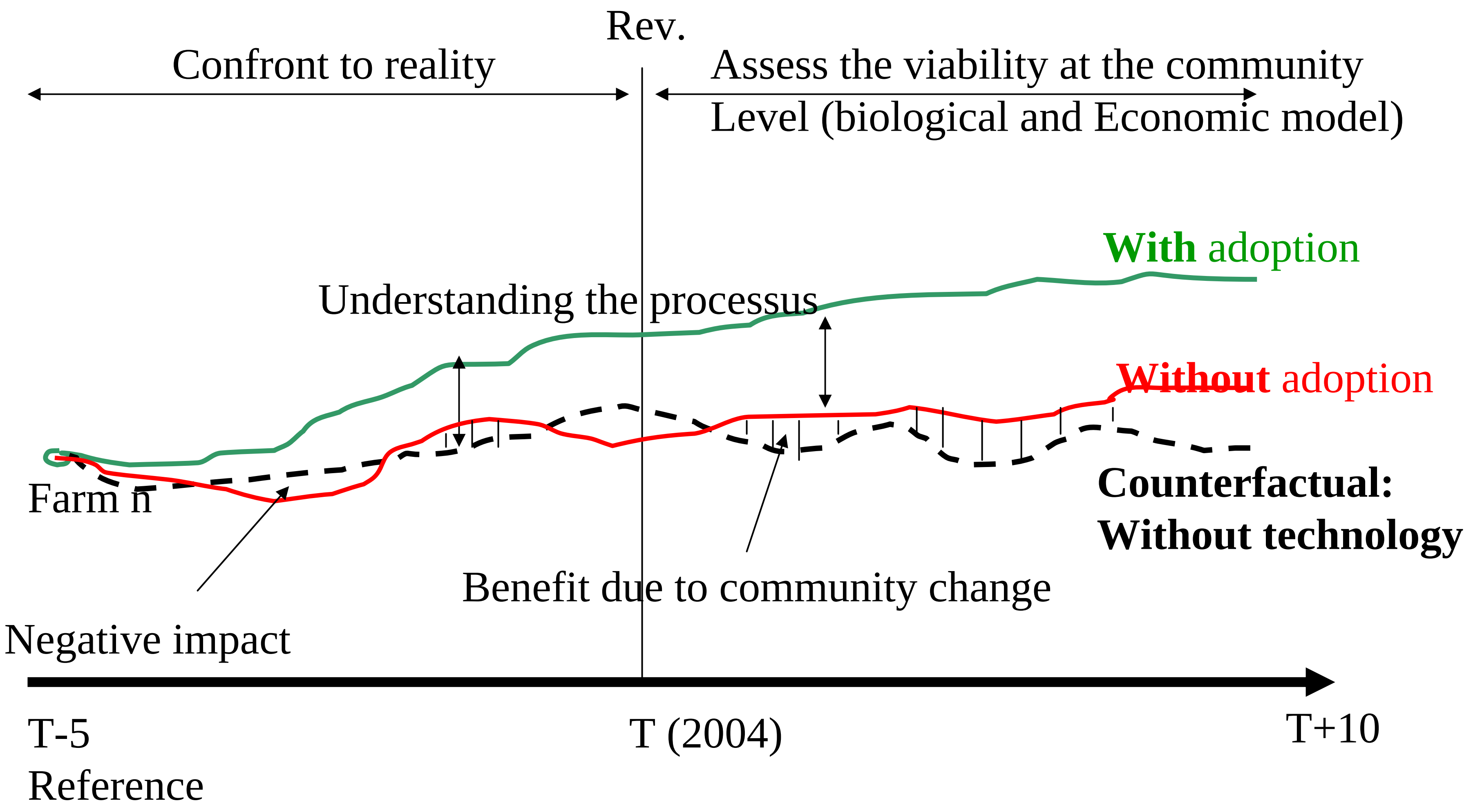


Ex Post Impact Assessment of NRM project

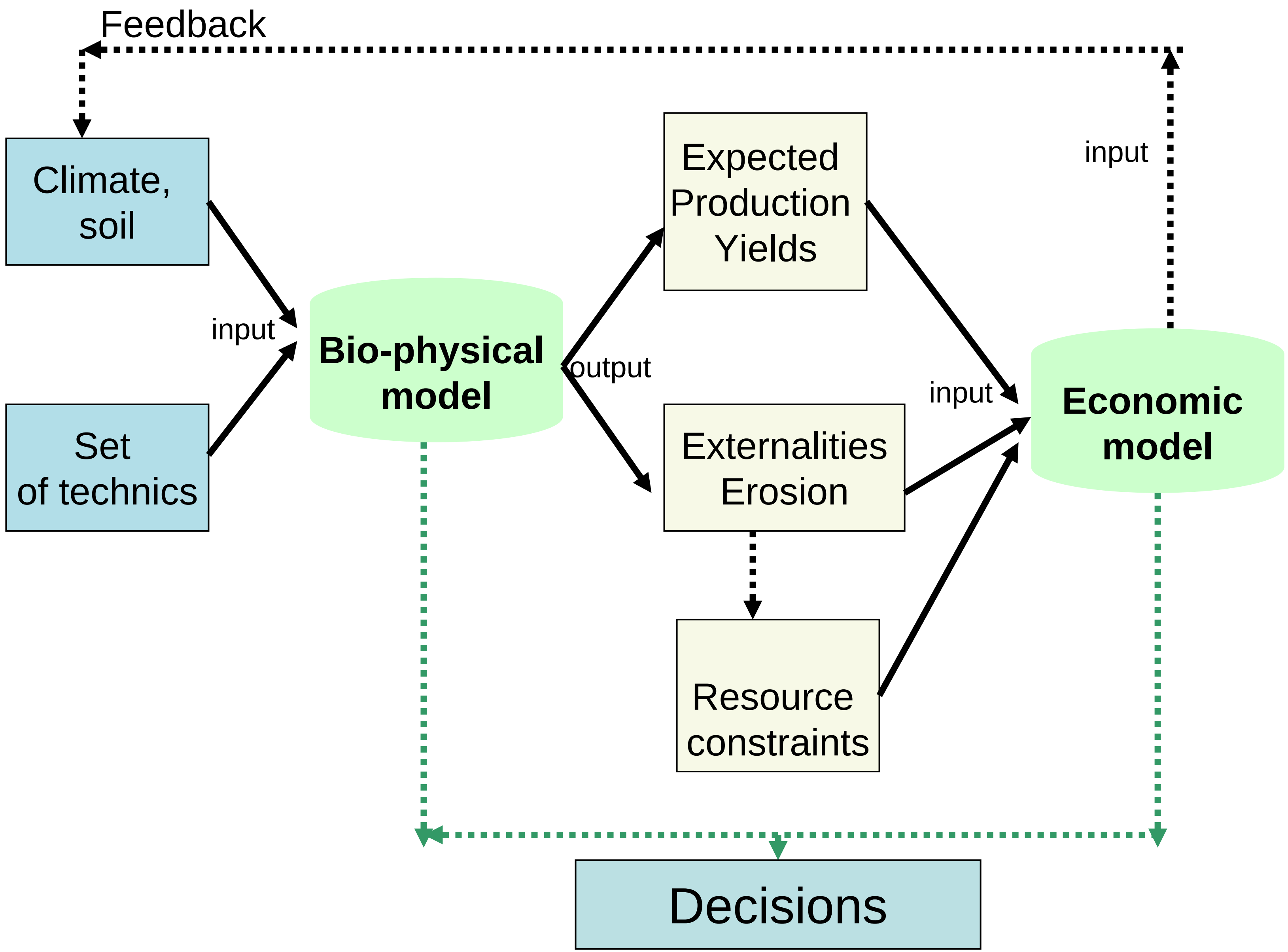
Problems of this approach:

- No taking into account the dynamic of these systems
- Natural Resource management needs to integrate the trade off between present and future
- Complexity of the interactions
- Pluri-disciplinarity

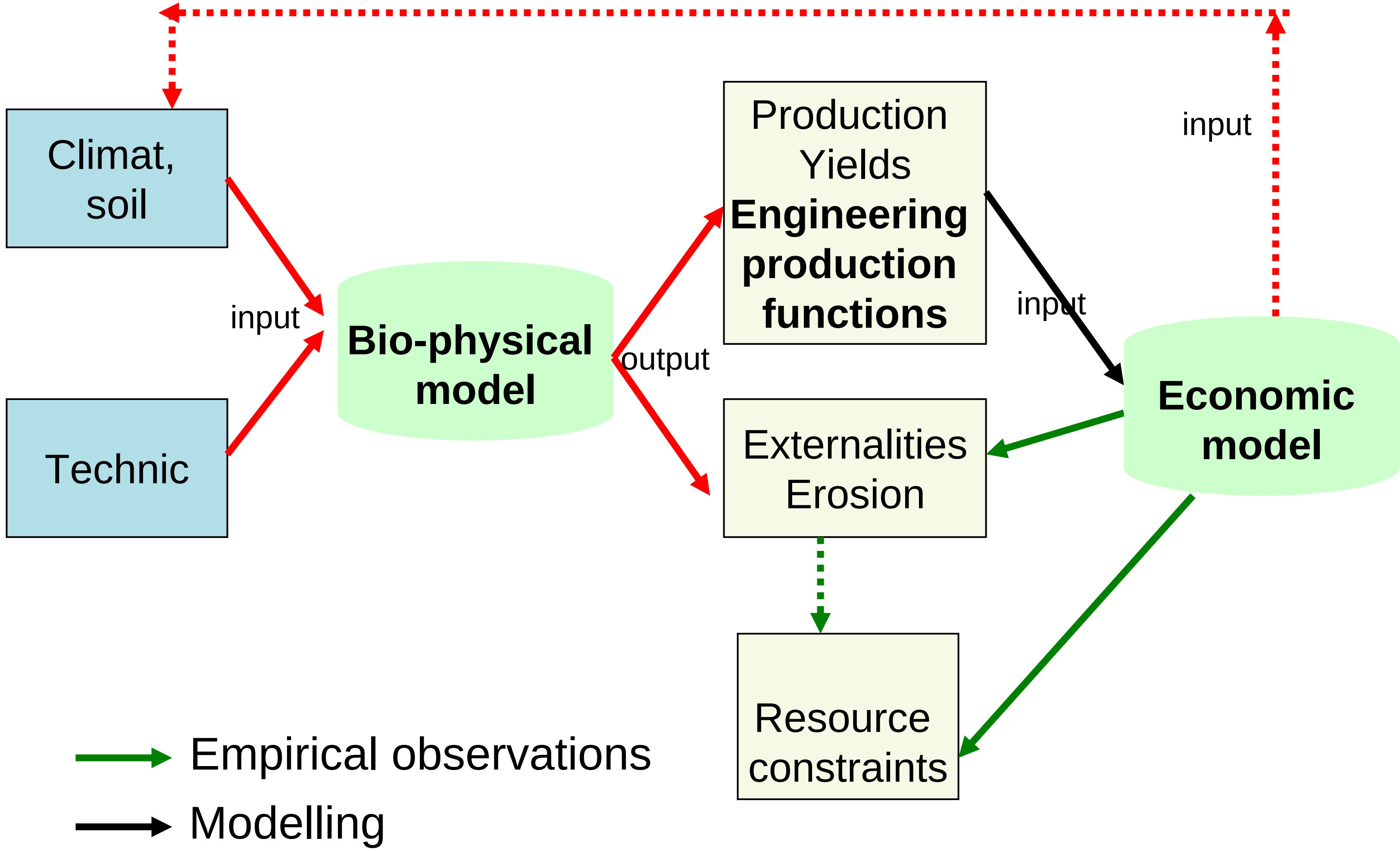
Extrapolation

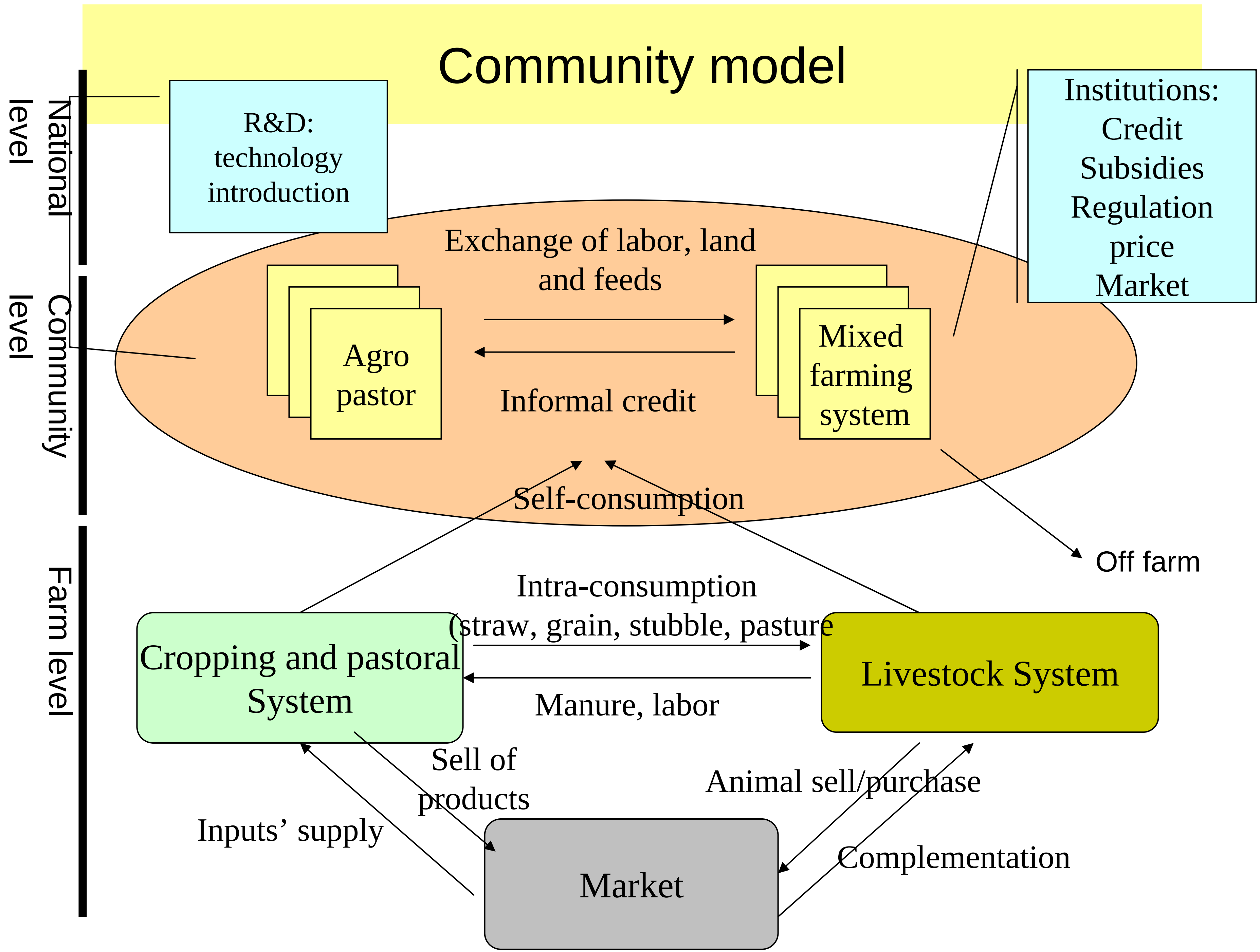


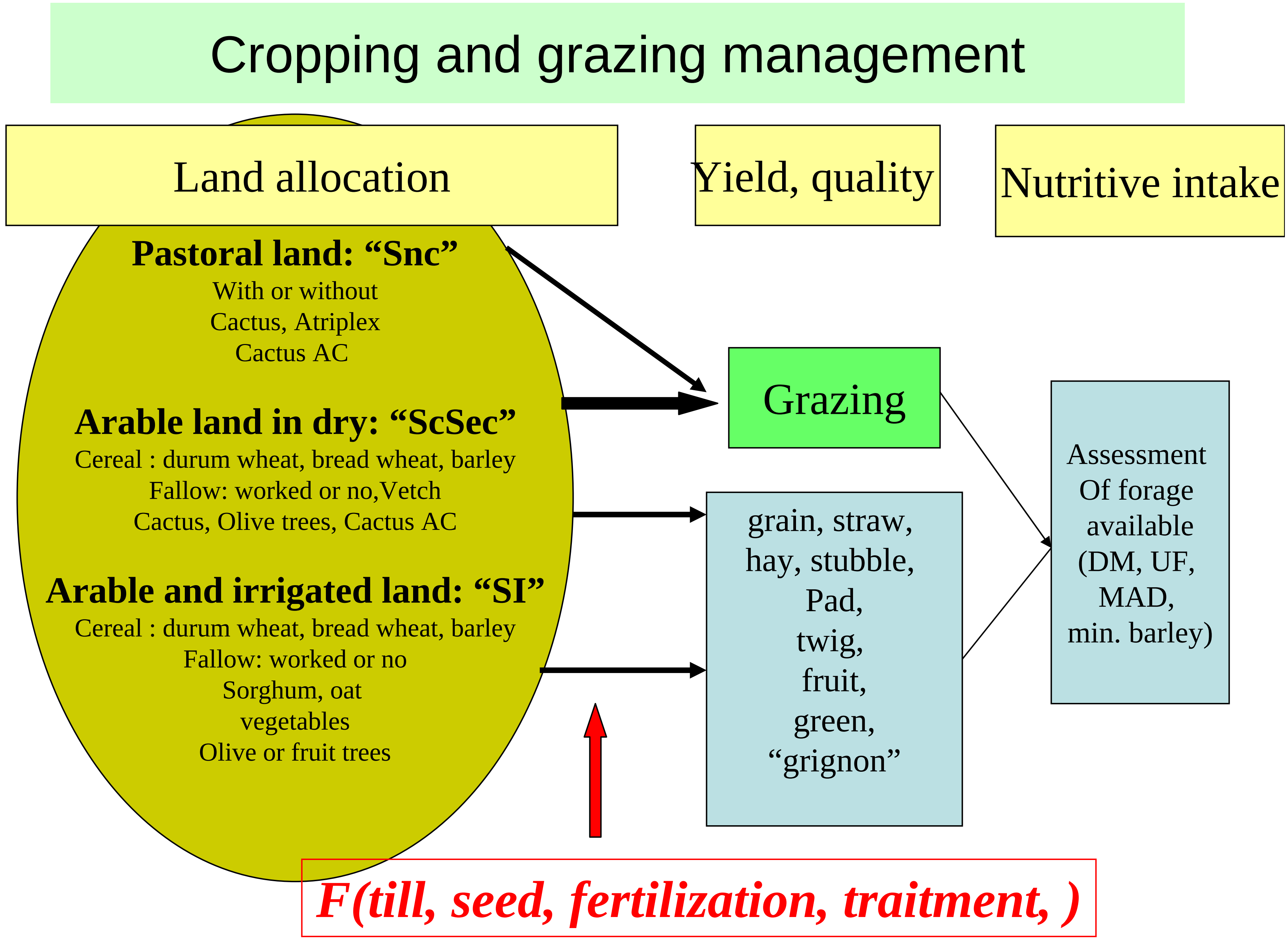
Bio-economic model



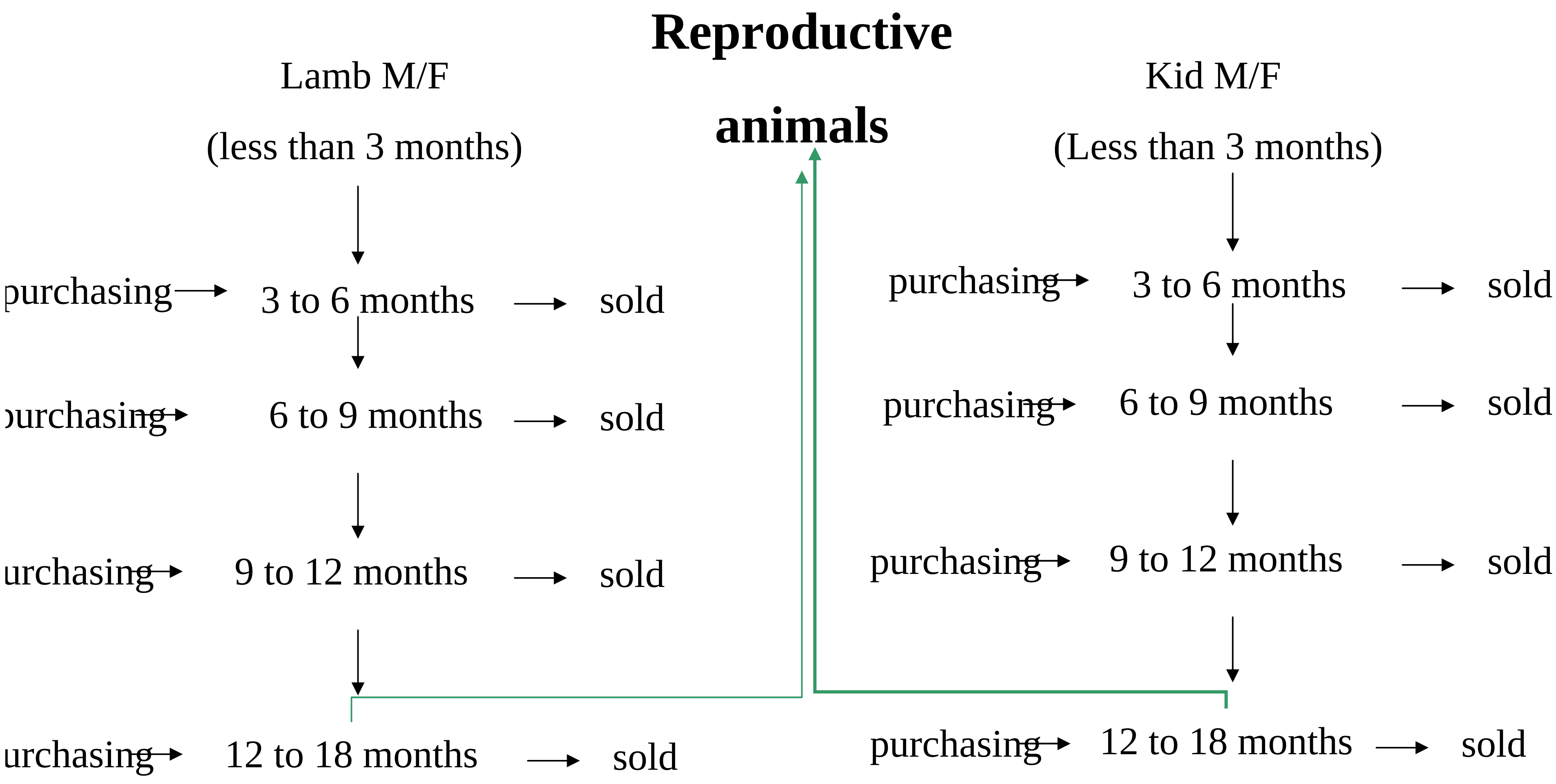
Limitation to approach the sustainability




Community model
National level
Community level
Farm level
R&D: technology introduction
Institutions: Credit Subsidies Regulation price Market
Exchange of labor, land and feeds
Agro pastor
Mixed farming system
Informal credit
Self-consumption
Off farm
Intra-consumption (straw, grain, stubble, pasture
Cropping and pastoral System
Livestock System
Manure, labor
Sell of products
Animal sell/purchase
Inputs' supply
Complementation
Market


Cropping and grazing management
Land allocation
Yield, quality
Nutritive intake
Pastoral land: “Snc”
With or without
Cactus, Atriplex
Cactus AC
Arable land in dry: “ScSec”
Cereal : durum wheat, bread wheat, barley
Fallow: worked or no,Vetch
Cactus, Olive trees, Cactus AC
Arable and irrigated land: “SI”
Cereal : durum wheat, bread wheat, barley
Fallow: worked or no
Sorghum, oat
vegetables
Olive or fruit trees
Grazing
grain, straw, hay, stubble, Pad, twig, fruit, green, “grignon”
Assessment Of forage available (DM, UF, MAD, min. barley)
F(till, seed, fertilization, traitment,)

Demography of the herd



Input/ Output coefficients

Cropping act. (ha)

Till, seed, fertilizer, traitment,

Investment (land management, planting, etc.)

Need in hour-work

Need in mechanization

Yield, Nutritive value, etc.

Animale act. (specie, age)

Complemention, ration

Investment (Building, genetic..)

Need in hour-work

Need in mechanization

Growth grain, yield,

Technical constraints

Constraints related to factors

Seasonal constraints

Land : **$\sum$X(pc) ≤ Tdisp(pc-1) +Tpurchase(pc) + Trent (pc) + Tassoc.(pc) - Tsold (pc) – Tgrent (pc)- Tgasso(pc) – Tplanted (pc)**

Labour : **NeedMO (pc) ≤ MO.SalPer (pc-1) + MO.f(pc-1) + MO. occa(pc) – Mof_sal(pc)**

Equipment : **NeedHT (pc)≤ HT.disp(pc-1) + HT. purchased(pc) + HT. rent(pc) - HTgrent(pc)**

Constraints related to livestock act.

Seasonal constraints

Animal demography

Nutritive need: **NeedNUT (pc) ≤ NUT. Disp (pc)**

Ration : **Cactus ≤ 20% DM need**

Concentrates ≤ 50% DM need

Economic constraints

➲**Short terme credit: Informal/community/Formal**

➲ **Emprunt à Long terme :**

Ceiling: EMPCT (PC) $\leq$ CCTLim (500 DT)
Guarantees: REMBT (PC) = EMPCT (PC-1)

➲**Threshol or break even point for the cash flow :**

CASH (PC) > CashLim (5000 DT)

➲**Risk : minimize the deviation relative to threshold of income (Z_0) defined in advance**

➲**Etc.**

Investments

- ➲ Purchase Animals
- ➲ Purchase equipments (mechanization, car, irrigation, etc.)
- ➲ Land management
- ➲ Purchase land
- ➲ Building

Own capital

Long terme credits

Cash Flow → recursivity

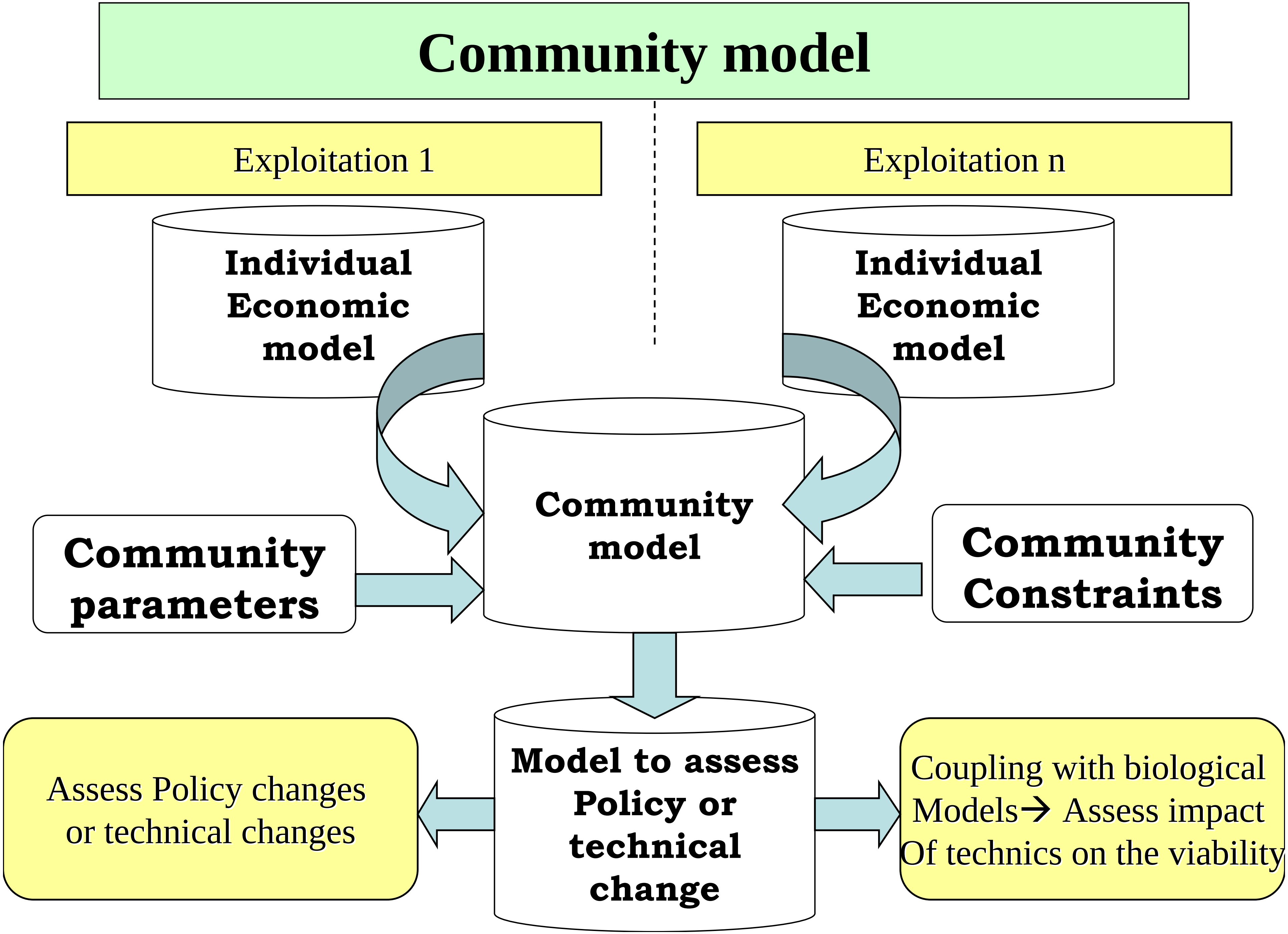
Balance (PC-1) + **Receipts (PC)** - **Expenditure (PC)** = **Balance (pc)**

Receipts (PC)

- Sold
- Subsidies
- Sold of services
- Interests on investment
- land incomes
- External incomes
- Short term credits

Expenditure (PC)

- variables charges (fertilizer, seed, carburant…)
- Fixed charges
- Financial charges
- purchased services
- land rent
- Family costs
- Reimbursement
- Saving


Community model
Exploitation 1
Exploitation n
Individual Economic model
Individual Economic model
Community model
Community parameters
Community Constraints
Model to assess Policy or technical change
Assess Policy changes or technical changes
Coupling with biological Models→ Assess impact Of technics on the viability

Objective function under risk constraints

$$\textbf{Max E(Z)} = \sum_{ye=t_0}^{T} \frac{C_{ye} X_{ye}}{(1+\tau)^{ye}} + K / (1+\tau)^{T}$$

With : $A\,X_{ye} \leq B_{ye}$; $B_{ye} = bX_{ye-1}$; $X_{ye} \geq 0$

Under risk constraints (Target Motad):

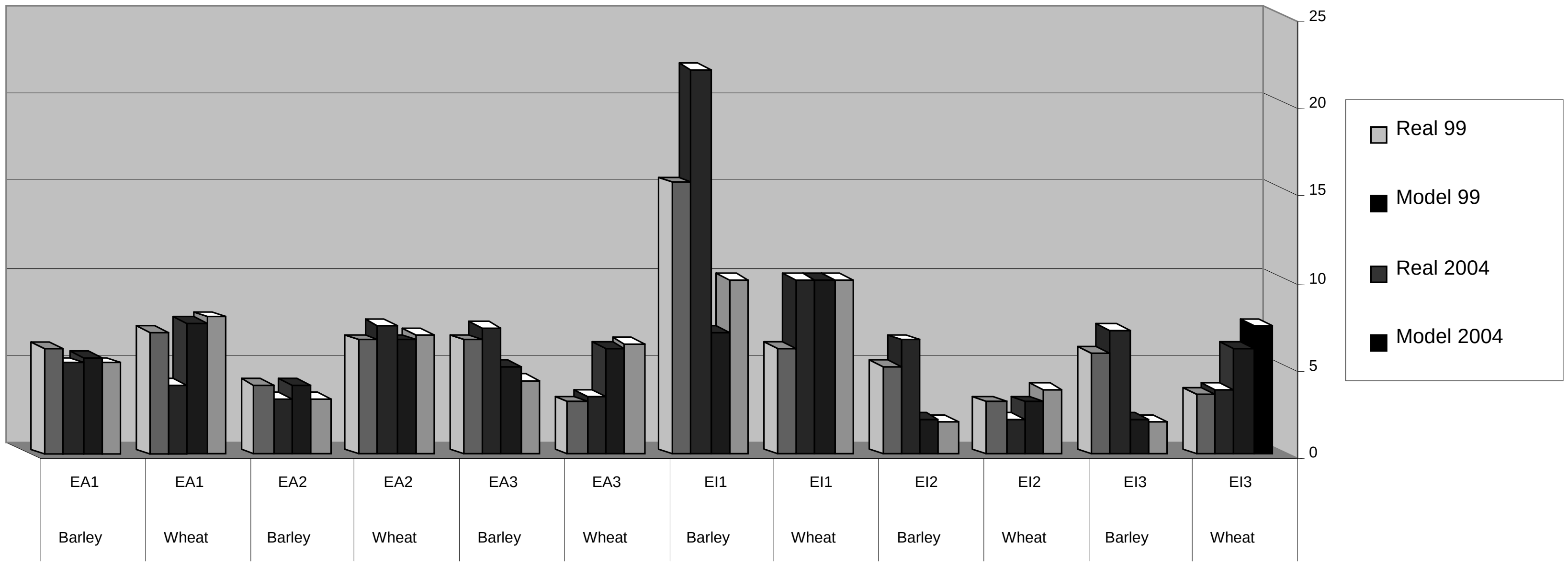
$$T - \sum_{j=1}^{n} C_{ye,j,r} \bullet X_{ye,j} - \lambda_{ye,r} \leq 0 \; ; \; r = 1,\ldots,s \; ;$$

$$\sum_{r=1}^{s} P_r \, \lambda_{ye,r} = \Omega \; ; \quad \Omega = M \rightarrow 0 \; ;$$

$$X_j \geq 0, \lambda_{ye,r} \geq 0 \; ;$$

Calibration/ Validation

Figure 6.2: Comparison of cereal area in 1999 and 2004 for each farm type



Calibration/ Validation

	1999/00	2000/01	2001/02	2002/03	2003/04
EA1	-33.98	-8.07	-5.64	9.78	8.41
EA2	-2.48	-6.33	-1.67	-14.34	-28.28
EA3	-5.62	-6.33	7.99	-4.43	-4.56
EI1	-8.21	-0.76	-3.65	11.28	6.88
EI2	6.02	6.88	2.65	-1.39	-13.89
EI3	-3.98	-27.15	-25.00	-9.11	1.83

Ewe stock

Cash Flow

Farm	Year of validation	Reference	Model	Deviation
EA1	1999	8382	8909.77	6.29
	2002	3240	3619.7	11.72
EA2	1999	1722	1931.447	12.16
	2002	1637	1909.07	16.62
EA3	1999	2259	2266.51	0.33
	2002	1307	1713.23	31.08
EI1	1999	8105	8461.4075	4.40
	2002	12137	12294.26198	1.29
EI2	1999	1798	1830.89	1.83
	2002	3942	3774.03	-4.26
EI3	1999	1798	1706.74	-5.07
	2002	2408	1090.51	-54.71
Average deviation	1999	24064	25106.7645	4.33
	2002	26205	24400.80198	-6.88

Ex Post Impact Assesement

To evaluate the impact assessment of the technology “cactus in alley cropping” :

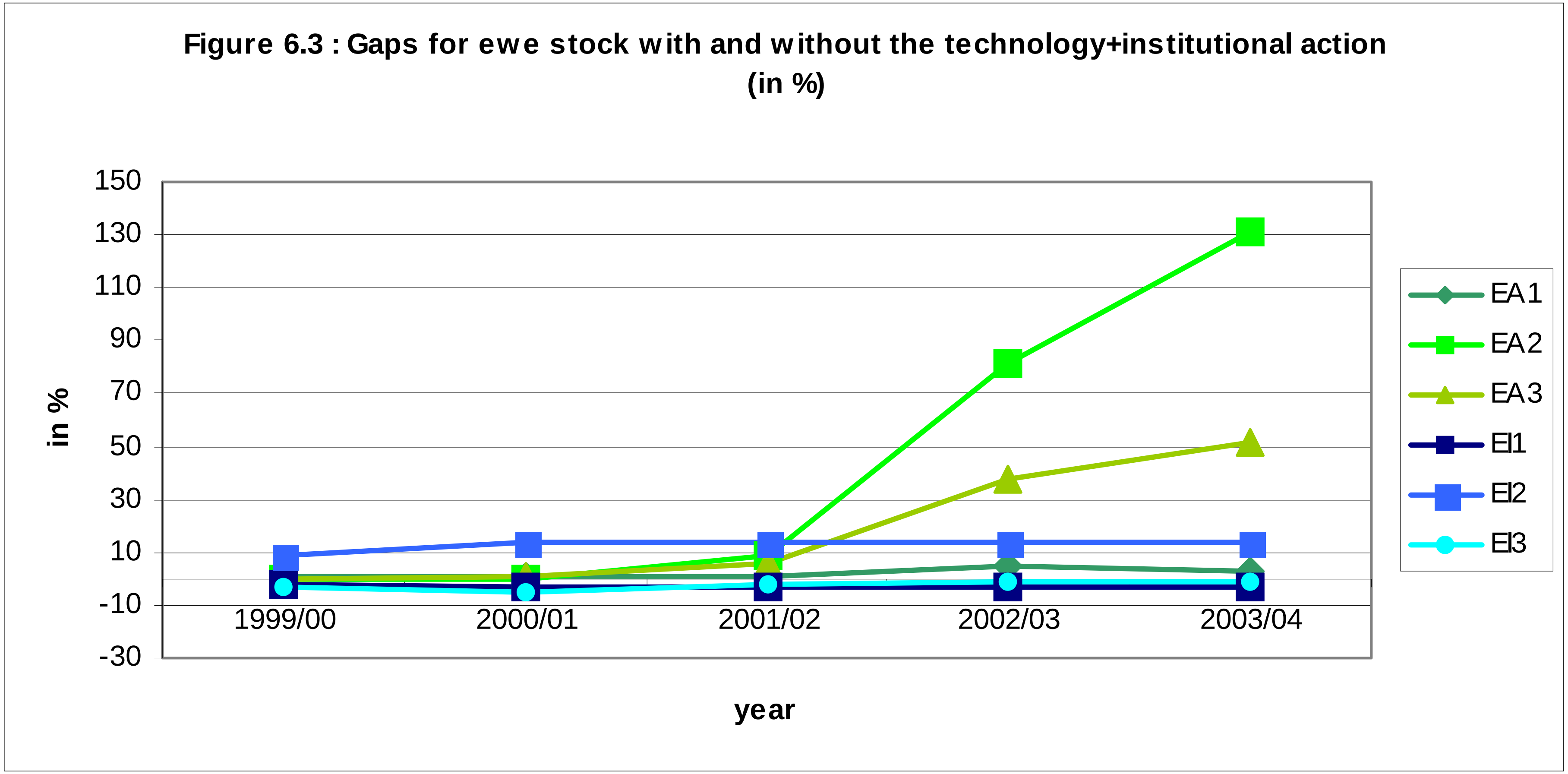
- **Scenario 1**: The technology option doesn’t exist. The farmers have only one alternative related to cactus is to plant whole area of cactus. This situation could be considered **as the counterfactual situation** and allows to estimate the all benefit of the technology at the farm level

- **Scenario 2:** The technology exists but there is **no funded project** to facilitate the adoption. We can compare the adoption level with and without the subsidies.

- **Scenario 3**: The technology exists with the funded project. **We will compare the real adoption with the adoption in the model.**

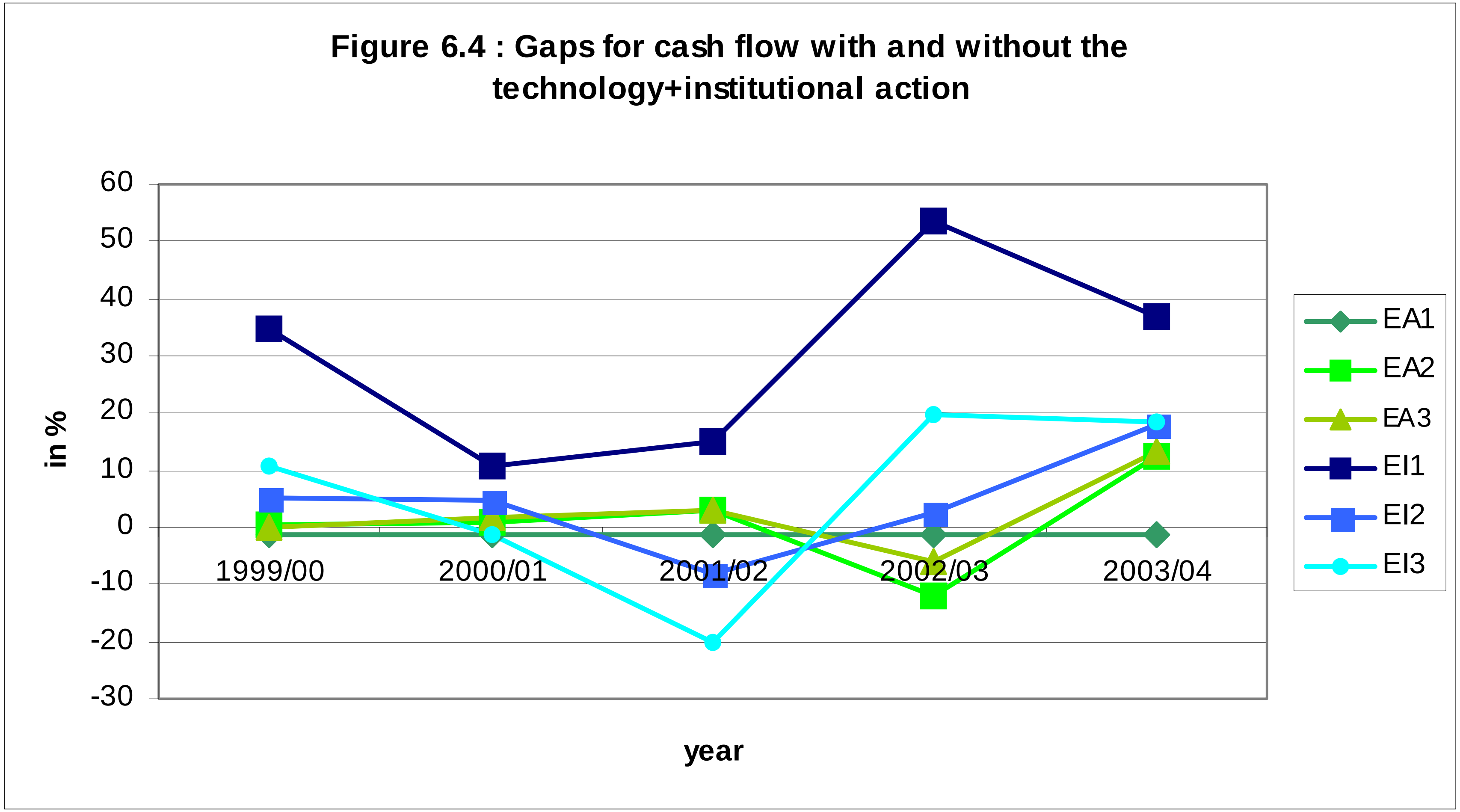
- **Scenario 4:** The technology exists with the funded project. **There is no restriction for the support**. We could estimate the potential adoption.

Scenario 1: Ex post Impact assessment of the technology & institutional environment



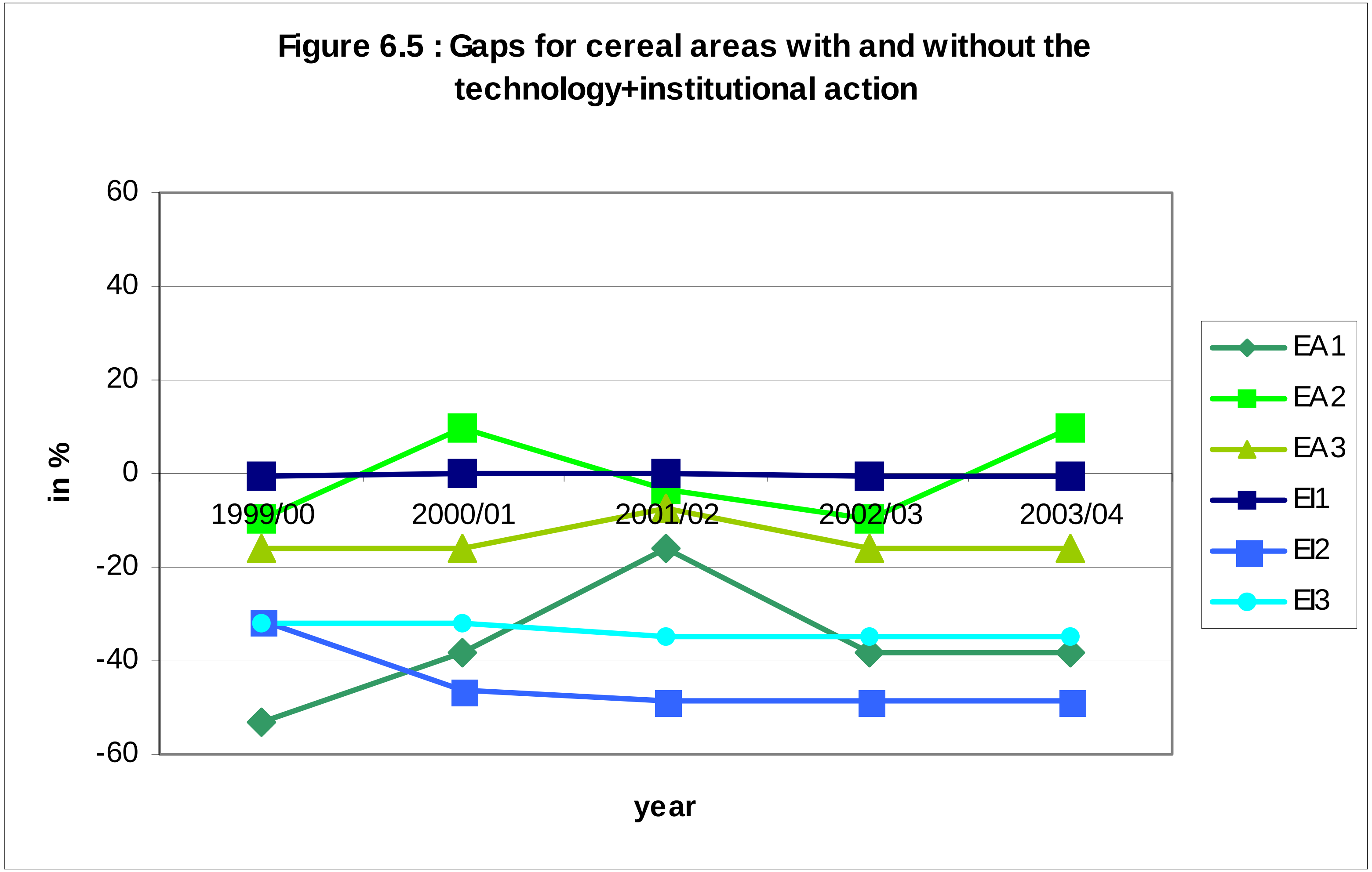
The annual average ewe stock is 6% more than in the counterfactual situation. So this confirms the role of cactus during drought years to avoid de-stocking.

Scenario 1: Ex post Impact assessment of the technology & institutional environment



The Zoghmar community registers in average an increase of 7 % of the annual cash flow. .

Scenario 1: Ex post Impact assessment of the technology & institutional environment



Reduction of traditional cereal system (5%), responsible of erosion

Scenario 1: Ex post Impact assessment of the technology & institutional environment

	1999/00	2000/01	2001/02	2002/03	2003/04
Reference with project	0.28	0.28	0.31	0.29	0.31
Counterfactual	0.28	0.27	0.31	0.26	0.29

No impact on poverty at the community level
But no distinction between cactus adopters and the others

Scenario 2 & 3: Ex post Impact assessment of the institutional environment

	S1	S2	S3	S4	Survey	
Farm	Adoption level without OEP incentive	Adoption level without OEP incentive+ 30% yield	Adoption level with limited OEP incentive	Adoption level with limited OEP incentive And yield increase	Area of cactus in alley cropping	Area with spine cactus
EA1	0	5.78	5	16.53	5	8
EA2	0	2.93	1	2.93	1	2
EA3	0.29	3.34	3.34	3.34	2	2
EI1	10.21	29.17	30	45.6	30	
EI2	2.67	3.85	2.67	3.85	0	0.5
EI3	0	10.75	5	11.23	5	1

Scenario 4 : Ex post Impact assessment of the institutional environment – Extension of public support

Scenario1	1999/00	2000/01	2001/02	2002/03	2003/04	reference
EA1	5.78	5.78	5.78	16.53	16.53	5
EA2	2.93	2.93	2.93	2.93	2.93	1
EA3	3.34	3.34	3.34	11.4	11.4	2
EI1	29.17	29.17	50	50	50	16
EI2	5.5	5.5	5.5	5.5	5.5	0
EI3	10.71	10.71	14.25	14.25	14.25	5

All the farmers increase their area three fold in spineless cactus in alley cropping, compared to baseline scenario.

First Conclusions

When we compare the area allocated to the technology between the different scenarios, **we can tell that a good information about the yield expectation with the technology could give similar adoption degree than subsidies.**

But it is true that the reality is more complex:

- The expected subsidies can be more crucial, especially considering that during dry years, the expected yield of cereal in alley cropping could be inferior to the subsidies
- Why implement alone this technology if we could profit from subsidies and yield increase in the same time? So some farmers are waiting…
- Good information at the community level is always difficult or even impossible
- As with good information, the level of believe in the information intervenes.

Other simulations

Figure 6.9 : Gaps for ewe stock with the cereal and meat market liberalization and without the technology+institutional action (in %)

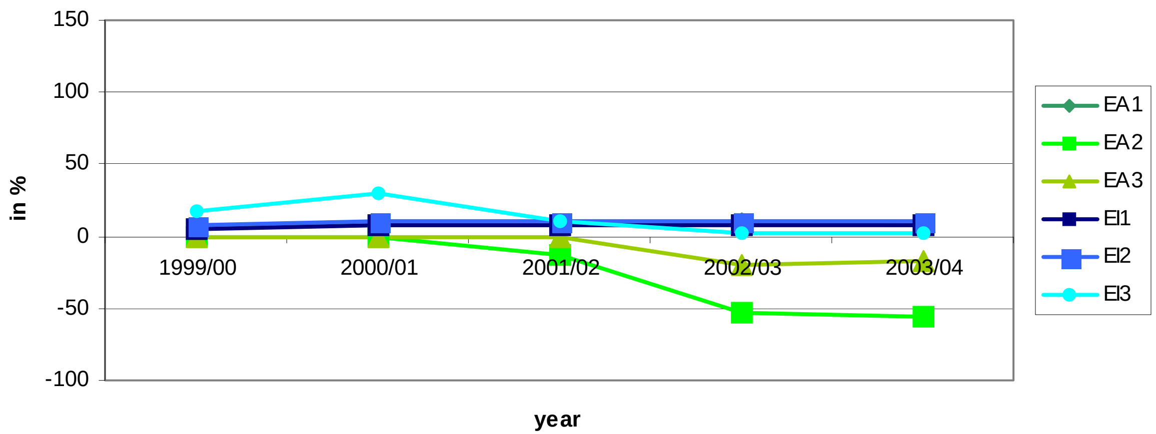
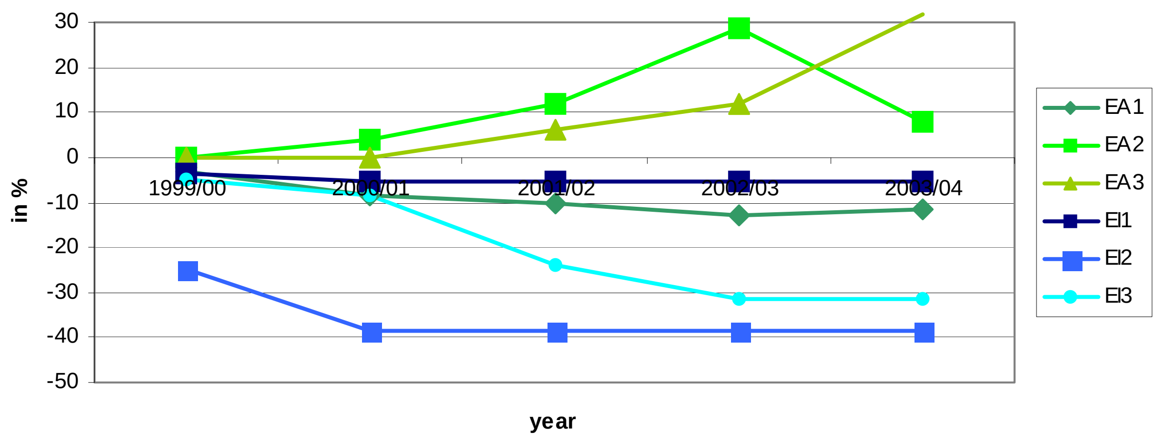


Figure 6.10 : Gaps for ewe stock with the cereal and meat market liberalization and with the technology (in %)



First Conclusions

This first results show that **a mathematical model could be used in an ex post impact assessment** and give new information compared to econometric or static methods of valuation.

But as for the classic methods, **the counterfactual situation is difficult to establish**. In this analysis the counterfactual situation is a simulation compared to the benchmarking which is the situation with the project.